ELECTROCHEMICAL STORAGE ELEMENT

- USSR -

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The development of computing technology gives
rise to demands for the creation of various types of
storage devices, capable of receiving information from
the arithmetic units of the computer machine, storing it,
and issuing it whenever required.

For various types of computer machines various
types of memory devices are necessary which differ in
their properties.

In some cases there come to the forefront require-
ments of high speed, fast recording rate and fast reading
rate, while in other cases, for example in relay machines,
or else in certain special-purpose machines, no great
speed is required, but on the other hand the paramount
requirements become small size of the memory element, low
power consumption, simplicity, and low case in manufacture.

There exist a large number of various types of
memory elements, based on electric and magnetic principles.

In the present article we describe a memory element
constructed on the chemical principle.

The principal requirements that must be satisfied
by chemical memory elements of modern computing machines
are high speed of the chemical processes and their
reversibility, i.e., the possibility of multiple recording
of the information. Many chemical processes satisfy the
requirement of reversibility (phase changes connected with
the formation of new modifications, many reversible
chemical reactions, etc.). However, these processes,
particularly those occurring in the solid phases, are very
slow -- on the order of tens of minutes and more --
which excludes them from use in computing machines.

The requirement of high speed is satisfied by
reactions that occur explosively. Explosive reactions,
however, are as a rule irreversible, and to return the
memory element to its initial stage it is necessary to
add a rather complicated construction, even if one dis-
regards the fact that the reverse process is many times
slower than the direct one.

Memory elements free of these shortcomings are
based on electrochemical processes of deposition and dis-
solution of metals on electrodes immersed in an electro-
lyte solution through which an electric current flows.

In our case the speed of the process is determined
by the speed of deposition of the metal on the electrodes.
Under known conditions the process is fully reversible.

As is known, when a metal is immersed in a solution
of salt with cations of the same kind, at a definite
concentration of this salt, the metal has a fully defined
electrode potential

$$E = E_0 + k \ln a,$$

where E -- electrode potential of the metal,
E_0 -- the standard electrode potential,
a -- the activity of the cations in the solution,
k -- a constant (when $T = const$).

If another metal is deposited on this metal, and
if the other metal has a more negative electrode potential,
then the common electrode potential of the system as a
whole will be closer to the potential of the second metal.
If the deposited metal has a very small concentration,
its potential cannot be measured, and can be determined
only starting with a certain finite concentration. The
time during which the precipitated metal accumulates on
the electrode will indeed be the time of operation of the
given memory element. It can be calculated by the Faraday
formula.

Thus, there is a real possibility of using electro-
chemical processes of deposition of a metal on an electrode
for recording information whenever a current pulse passes
through the cell, or the return of the metal in the form
of an ion into the solution whenever a current pulse of
opposite polarity passes through the cell to erase the
information.

Let us consider the construction of the proposed memory element. This element is an electrochemical cell, consisting of three electrodes: one zinc and two of the same metal -- working and standard, which are plates of refined copper amalgamated with mercury. The passage of a current pulse causes zinc to be deposited on the working electrode and to change the potential of this electrode, while the standard electrode has a fixed stable potential. The working and the zinc electrodes are in one vessel, the standard electrode is in another one, and both vessels are connected by means of an electrolytic key (Fig. 1). The electrolyte used is a saturated solution of zinc sulphate with a small amount of mercurous sulphate added.

To record the information we apply a plus voltage to the zinc electrode and a minus voltage to the working electrode. Zinc is deposited on the working electrode in accordance with the following reaction

$$Zn^{++} + 2e \rightarrow Zn.$$

A zinc amalgam is produced, and the following electromotive force is produced between the working and standard electrodes:

$$\Delta \varphi = \varphi_{c\tau} - \varphi_{Zn},$$

The magnitude of the electromotive force for electrodes made of amalgam of copper and zinc is 1.1 volt.

Figure 2 shows the variation of the emf with time during the process of recording and erasure. These data show that the current delay of the element coincides with the time delay of ordinary electromagnetic relays, which makes it possible to use this electrochemical memory element extensively in relay computing machines.

No separate voltage source (1.5 volts) is needed for the recording of the information, as the 12 volt standard used in relay circuits can be used, since in character of operation of the cell.

We considered above the operating principle and the operation of an individual memory cell. If cells are joined in a common block, the zinc and standard electrodes of the latter are interconnected and consequently, one zinc and one standard electrode is used in a system containing several working electrodes.

Generally speaking, zinc is deposited on the standard electrode during recording, but since the area of the standard electrode is chosen such that it exceeds by many times the areas of the working electrodes, the processes that occur on the standard electrode during the recording time (accumulation of zinc amalgam) can be neglected. During erasure the zinc on the standard electrode is dissolved. The authors have prepared an experimental block consisting of 48 elements, measuring 70 x 30 x 20, i.e., each element occupies approximately 1 cubic centimeter. Such a structure readily admits of mechanization of the manufacture by stamping. One first stamps the upper part of the vessel together with the working and combined zinc and standard electrodes, and then, after forming the amalgam on the electrodes (the electrodes are held in a solution of mercury nitrate for 10 or 15 minutes) the bottom is glued to the vessel. The vessel is filled with the electrolyte through two holes in the upper portion, which are then tightly closed by threaded plugs. In such a method a large number of elements is prepared immediately, the cost of manufacture per element will obviously be small.

Let us examine now the question of using this element in the general circuitry of a computer machine.

In order that no information be lost during the process of recording, the electrode current must not be greater than 10--15 microamperes. For this purpose the recording can be made through a high-resistance amplifier, the output power of which is in turn sufficient for operation of an electromagnetic relay.

The authors have used an amplifier made up of two P1E diodes; the imput resistance was 100,000 ohms, the amplifier produced practically unlimited number of reading cycles. Since the amplifier is larger and more expensive than the memory cell itself, the address decoder should ensure operation of a large number of memory elements per amplifier. One of the possible solutions is to use a stepping selector as a decoder. Thus, a stepping selector ShI-50/8 can operate with 400 memory cells (50 eight-digit binary numbers) using eight amplifiers (one amplifier for each column in all 50 numbers).

Conclusion

Electrochemical memory elements can be used successfully in relay computing machines and special machines which do not require high working speeds.

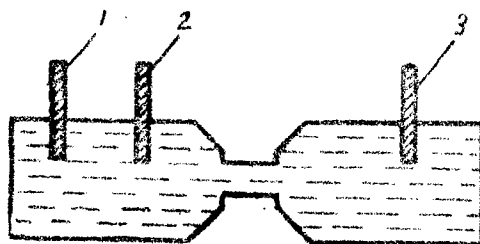Figure 1. Section through the memory element.

1 -- zinc electrode, 2 -- working electrode, 3 -- standard electrode
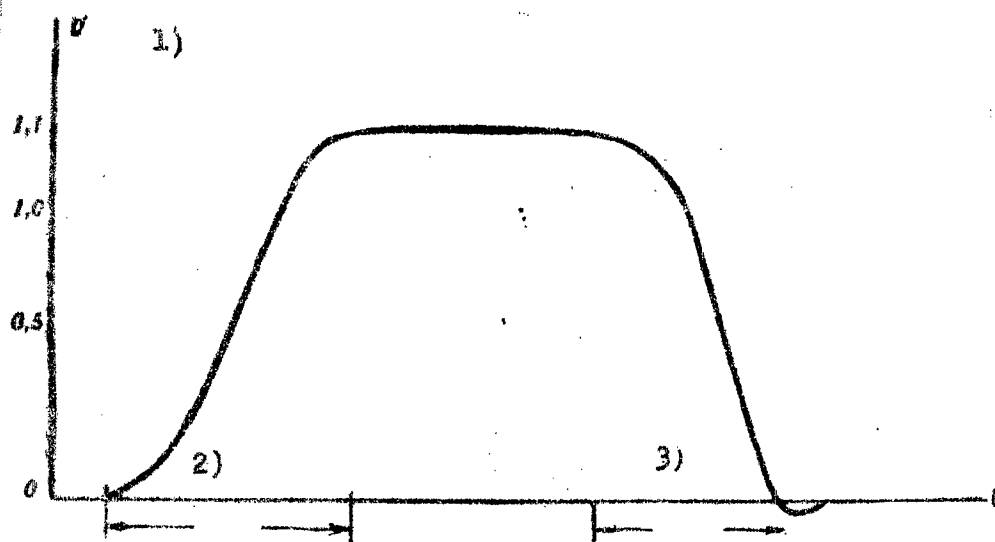
Figure 2. Recording and erasure
processes

1) U, volts 2) Recording, 30 milliseconds
3) Erasure, 20 milliseconds

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